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# The optimization of cocoa quality through nitrogen as a replacement of light limiting

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## Abstract

Cocoa has been cultivated in the yard with many limiting factors especially light intensity. The attention of cultivation is needed for obtaining high quality of cocoa through appropriate fertilization as a replacement of light limiting. Punung Pacitan in the central of Java Indonesia is the place of cocoa plantation since 2009 and still in the low production. Balancing fertilization is required to anticipate low light interception through the availability of nitrogen. The aim of research is to find the dose of nitrogen as light limiting replacement factor, and to evaluate the level of light interception that appropriate for cocoa. Type of research is descriptive quantitative by survey at three locations based on shade condition differences and application of nitrogen enriched fertilization. Seed have a fat, protein and phenol content as big as 47.34%, 20.57%, 6.0% respectively, although be planted below the tree (light interception is 13.60% from the average of 799 lux meter). It means that limiting factor of light interception can be compensated by nitrogen fertilization to increase seed quality. This research proves that nitrogen can be used as a replacement factor of light condition and the dosage of 850 g per tree per year can fulfill nutritional needs.

***Keywords:*** Quality Of Cocoa; Nitrogen Fertilizer; Light Limiting Factor



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## 1. Introduction

Cocoa is the high of economic value and be the third level of commodity which contributes to exports and foreign exchange (Suryani, 2007). International Cocoa Organization (ICCO) in 2007 declared Indonesia was the third largest of cocoa production in the word after Ghana. Cocoa production in Indonesia (2016) is as big as 760,429 ton from 951,901 ha of planting area. The largest production of cocoa is come from Sulawesi in 2016 with production capacity as big as 494,241 ton from 593,165 ha of planting area (Ditjenbun, 2015).

Cultivation technology has been done such as soil tillage, nursery, maintaining until post harvesting but national productivity is still low due to limited resources condition and the low intensity of maintaining (0.7 compared with 2-3 ton per ha of potential product). Based on the potential product, it can be explained that 1.5-1.7 million ha of planting area be able to produce 1,050,000-1,190,000 ton per year and if the production be upgraded until 1 ton per ha so the Indonesian cocoa production can achieve as big as 1,500,000 ton per year (Prabowo, 2015).

Punung village in Pacitan regency is the part of cocoa production in East Java. However result of research showed that the production of seed only 0.3 ton per ha per year and it means only 50% from national production (0.7 ton per ha). It showed that cocoa cultivation be planted in the yard with many limiting factors of growth such as light intensity, soil fertility and maintenance aspect. Besides environmental condition, the knowledge of cocoa nutrition requirements does not adequate for optimizing the growth and development. The limiting factor of light is caused by shade that becomes from many trees in the yard such as coconut (*Cocos nucofera*), banana (*Musa* sp), jackfruit (*Artocarpus heterophyllus*), and several of fruit trees.

The increasing of quality and quantity of cocoa should be based on problems solution. The main problem is shade variation condition because of cultivation below the tree. It brings up on less lighting that gives impact on photosynthesis. Therefore, it are required research of the needed for light interception and micro climate modification for the better condition. Nutrient constrains can be solved by fertilization as the important factor for determining production (Stefanelli et al., 2010, Marzouk and Kassem, 2011).

The low level of light intensity gives impact on the forming of “b chlorophyll” as an antenna pigment for capturing light energy that makes “a chlorophyll” releases electron. This research wants to analyze the role of nitrogen fertilizer as a replacement of light constraint. It is very realistic due to role of nitrogen that influences chlorophyll development and finally becomes a solution for overcoming low light intensity (Taiz et al., 2015). Plant has capability to adapt on low light condition by increasing the content of “b chlorophyll”.

## 2. Material and method

This is the second year of research that is conducted in Punung Pacitan regency especially at Jatisari, Klepu 1 and Klepu 2 villages with the positioning geographic as follows 08°06’428’’S dan 111°01’55,5’’E (observed by GPS/*Global Ksitioning System* Garmin eTrex 30), from April until August 2017. The micro climate condition consist of rainfall intensity (1800 mm.year$^{-1}$), daily temperature (30°C), and soil humidity (50-60%), be collected from relevant agency and be measured by specific equipment (thermometer, soil tester, lux meter

Lutron LX-103). The chemical of soil be analysed by Kjedahl (N total), Olsen (available of P), and ammonium acetate saturated method (cation exchange capasity).

The content of N, total of P and K on leaf tissue be analyzed by special method (Kjeldahl, $HNO_3$ and $HClO_4$ destruction), at every levels of altitude and moment (after harvest, initiation of flowering, fruit formation and harvest). The quality of seed consists of the content of caffeine, protein, fat and phenol (are analyzed by spectrophotometer, kjedhal, and soxhlet method) and the number of seed per 100 grams. The Department of Soil Science and Food Technology in Agriculture Faculty Sebelas Maret University are the places for analyzing. All of the data be processed by F test (ANOVA) and if there is significant different be continued by Duncan Multiple Range Test.

Nitrogen fertilizer is applied on three location that based on the level of light intensity (high:Jatisari, medium:Klepu 1 and low:Klepu 2) through three steps, be fertilized after harvest, initiation of flowering and fruit formation. Phosphor and potassium are applied at the same time. Cocoa is collected from four trees on every locations and be analyzes the element content of seed. Furthermore, the amount of seed per 100 gram is also calculated. In the end of research, the absorption of nutrition be identified by leaf tissue analyzes.

## 3. 3. Result and discussion

### 3.1. Micro climate condition

The specification of tree canopy determines the level of light interception on cocoa canopy. The growth and development of plant always be affected by light radiation that reaches canopy (Taiz et al, 2015, Zorb, 2014). The average of light interception on cocoa at every location (Jatisari, Klepu 1, Klepu 2) are 11, 7 and 4% which mean not enough for fulfilling plant development. The maximum photosynthesis is obtained if light interception has captured by canopy as big as 20% of light intensity at open area. Leaf has optimal photosynthesis that connects with light saturation on a range between 3-30% and 15% of light intensity at open area. Those connect with the performance of stomata that will open maximum when accept the high level of light intensity (Karmawati et al., 2010). Light intercepted by canopy of cocoa be shown at Figure 1.

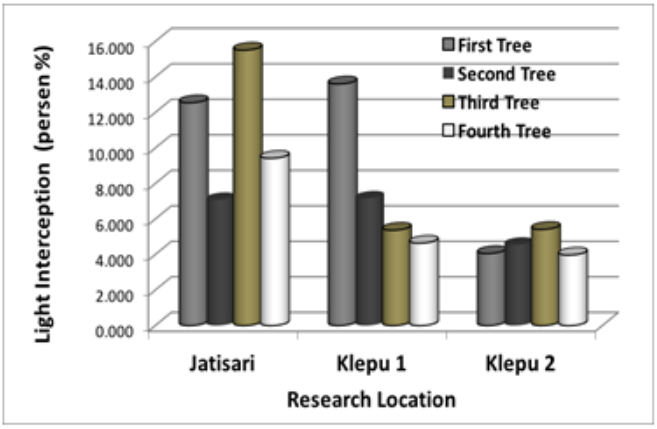


**Figure 1.** Light interception of cocoa on three research locations (source: primary data)

## 3.2. Seed quality

The quality of seed has been valued by the number of seed per 100 g and element content on seed (Pusat Penelitian Kopi dan Kakao, 2015). There is significant different between second and first year of research that is shown by number of seeds per 100 g, 80-100 seeds in the second year of research are compared with ≤ 85 on the first year of research and becomes AA category. It means that seed quality has just increased based on the changing of classification from A and B to AA (Departemen Perindustrian, 2007).

The element of seed consists of fat, protein and phenol which has been increased on second year of research as shown on Figure 2. Limited of light gives impact on rate of photosynthesis which is slower than normally light. It means, light intensity which is captured by "b chlorophyll" cannot stimulate "a chlorophyll" to release electron (Taiz and Zieger, 2015). So, it is necessary to make low light intensity useful on photosynthesis through enhancement of "b chlorophyll".

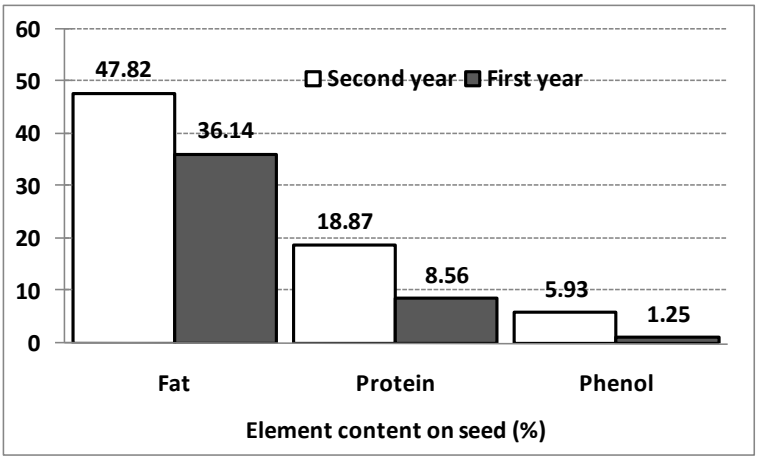


**Figure 2.** Elements content on seed (primary data sources)

Element content on seed has increased significantly after the application of nitrogen fertilizer. The enhancement of nitrogen has affected on synthesis of "b chlorophyll" so that the ability of "b chlorophyll" to catch the light will increase automatically. Furthermore, the performance of "a chlorophyll" to release electron will run well.

## 3.3. The content of nitrogen, phosphor and potassium on leaf tissue

The content of element on leaf tissue is assumed as the capability of plant to absorb its element. The absorption of nitrogen at high, medium and low light intensity is not significant (Figure 3). The low light of intensity caused nitrogen absorption on cocoa higher (Klepu II) than otherwise condition (Jatisari and Klepu I). It means that protein and chlorophyll synthesis will increase on the low light condition and be replaced by nitrogen fertilizer. Another case, phosphor absorption will decrease on low light condition but increase on the otherwise condition (r: 0.99). It is because of light reaction decreasing on photosynthesis and respiration

that be affected by low temperature (Taiz and Zieger, 2015). The absorption of potassium increases on low light condition (r: -0.67), as a reaction of plant to face the changing of environment condition (drought, salinity, high light intensity, low temperature, mechanism defense of pest and diseases) (Zorb et al., 2015).

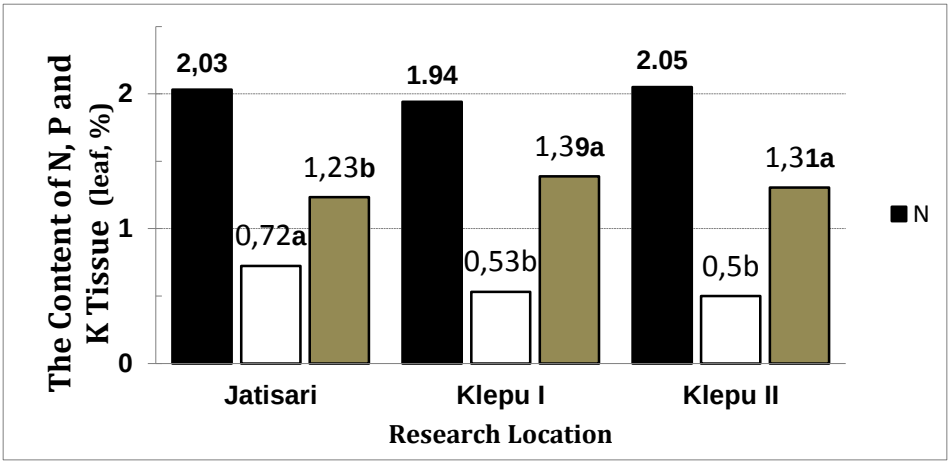


**Figure 3.** The content of N, P and K on leaf tissue (before fertilization, after harvest)

## 4. Conclusion

The conclusions of research are:

1- Cocoa cultivation can be done on medium light intensity as big as 15-30% of light intensity at the open area. That condition has increased the quality and quantity of seed which is caused by enhancement of nitrogen fertilizer (850 grams per tree per year) as a replacement factor of limited light.

2- The number of seed per 100 g on the second year of research showed significant different which is compared with the first year of research, 80-100 seeds are compared with ≤ 85 and be categorized on AA by Standard Nasional Indonesia.

3- The content of seed consists of fat; protein and phenol become increased significantly.

4- The absorption of N, P and K has increased from the beginning of fertilizer application. There is effectively fertilization which is based on the increasing of absorption.

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